The “Caddie Paradigm”: a Free-Locomotion Interface for Teleoperation

Patrick Lemoine, Mario Gutiérrez, Daniel Thalmann, Frederic Vexo

Swiss Federal Institute of Technology at Lausanne (EPFL), Virtual Reality Lab (VRlab)
Lausanne Switzerland CH-1015
tel: +41-21-693-5214   fax: +41-21-693-5328
{patrick.lemoine, mario.gutierrez, daniel.thalmann, frederic.vexo}@epfl.ch

Abstract

This paper presents the “caddie paradigm” a new interface for teleoperation of mobile robots. We present a prototype based on the use of a treadmill as a free-locomotion interface. The “caddie paradigm” allows for controlling a real robot by “pushing” its virtual representation displayed on a large projection screen. This system lets the operator walk right behind the robot situated in a remote location. A discussion on the advantages of the interface is presented. The implemented prototype shows the feasibility of using this paradigm of interaction to control robots remotely.

Keywords: virtual interfaces, teleoperation, haptic interfaces, locomotion and navigation systems.

1. Introduction

The work we present in this paper is related to the field of interfaces for teleoperation of mobile robots using Virtual Reality technology. We propose a paradigm of interaction to tele-operate a mobile robot.

Teleoperation systems are targeted to remotely drive robots working in places unaccessible to the human operator. Interaction with the remote device -robot- is typically achieved through physical controls: joysticks, steering wheels. Video cameras mounted on the robot provide visual feedback. Recent teleoperation systems have implement a master-slave architecture based on haptic interface devices such as exoskeletons and stationary devices, gloves and wearable devices, locomotion interfaces and full body force feedback [3], [2], [6], [4]. Latter work has improved the parameterization of the interface through the use of personal computers.

In our context of research we focus on finding better paradigms for direct teleoperation. We search for the best way to establish a dialog –interface- between user and robot.

To drive the robot, we take into consideration a paradigm used in several video games: driving a vehicle from a third person perspective. Third-person view allows for presenting more information about the state of the object under control: we can know whether it is turning or advancing straight, where it is located in the scene, etc. Concerning the actual transmission of commands from the user to the robot, we drew inspiration from a common activity which is intuitive and easy to learn: pushing a caddie in a supermarket.

A caddie is an easy-to-drive vehicle, the driver only needs to push and orient it with the hands while walking. We decided to mix both concepts in the form of a semi-immersive VR system for teleoperation. The user can walk behind the robot and have a better view of the scene, hence a better control. We call it “the caddie paradigm”.

A large projection screen (semi-immersive system) is used to display a virtual third-person view of the robot under control, along with live video coming form a webcam mounted on the robot. Driving a caddie requires walking; a natural choice was to use a locomotion system based on a 1D-treadmill.

Several treadmill devices have been used in VR applications as locomotion techniques, e.g. [7], [9], [8].

In this article, we first describe our paradigm of interaction based on the concept of **mediators** [6]. Then we describe the system architecture and discuss the results obtained with the implemented prototype.

2. Mediators

Our research is focused on finding the best interaction paradigms for direct teleoperation. In [6], we presented the concept of **mediators**: simple entities that serve as interface to more complex environments.

Our work with the concept of **mediator** let us evaluate the feasibility of using 3D models with haptic feedback as an intermediary to remote control virtual entities. In [4] we showed the feasibility of driving virtual and real robots using mediator interfaces with force feedback provided by a Haptic Workstation™ [5].

In this paper we present a different way to use mediators to control a complex system (a mobile robot). The "caddie paradigm" is an interface that uses very intuitive actions such as walking and hand-gesturing. This novel technique eliminates the need for direct manipulation of virtual controls with haptic feedback as used in [4] and [6]. Direct manipulation revealed to be difficult due to lack of precision of the haptic hardware.

The "caddie paradigm" allows for driving using hand gestures and relatively free locomotion (walking). The interface is complemented with a virtual representation of the controlled robot from a third-person perspective. We believe this visual representation of the information allows for achieving a better understanding of the system under control and improves the immersion in the task.

In the next section, we describe in detail the teleoperation system we have developed based on the "caddie paradigm".

3. A teleoperation interface

The "caddie paradigm" has been implemented as a teleoperation interface using a treadmill as the main input device (the interface for "pushing" the robot).

In order to maximize the ease of use, the user can only walk in one direction and simple hand gestures are required only for changing the heading direction of the robot.

Once again, we followed the metaphor of a caddie: to turn a caddie we push with more force with one of the arms. In our system, the user will advance his arm to indicate he wants the caddie –robot- to turn. Going backwards is done by advancing both hands at the same time (See figure 1).

Figure 1: 3 hand-gestures to control a real robot.

In addition, we required to measure the walking speed of the user in order to map it to the power to be applied to the robot's engines.

Our solution was to equip the treadmill with two webcams and use them to acquire both the user gestures and walking speed.

4. System architecture

This section presents the system components and how they relate to each other. The architecture divides the system into three parts:

- **Mediator Control System:** a virtual space, where we have defined a visualization paradigm to represent the controlled robot.

- **Robot Control System:** The remotely controlled world, constituted by a Lego-based mobile robot driven through an infrared serial interface.

All systems are connected to the Internet and communicate between each other using TCP or UDP protocols (See Figure 2).

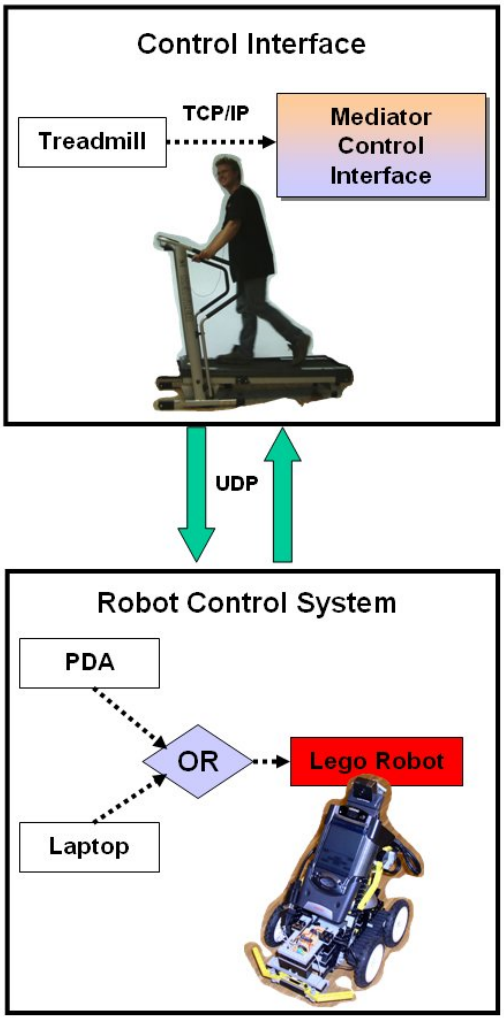

Figure 2: Elements of "Caddie paradigm" interface.

Mediator Control System

The current set up involves a semi-immersive locomotion interface that allows a user to walk through a pseudo-virtual environment. User is really walking on a treadmill and looking at a big screen. The interface shows the view obtained from a wireless webcam mounted on the robot. A 3D representation of the controlled robot (third-person view) is available as well (See figure 3).

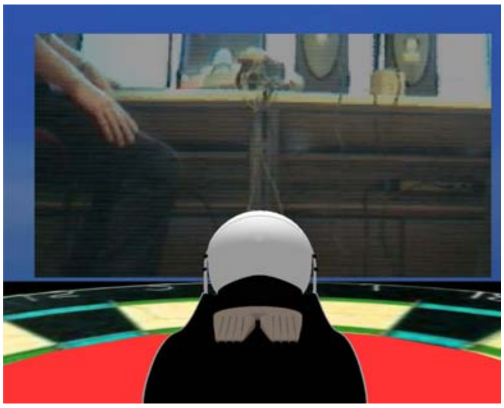

Figure 3: Mediator interface: virtual robot and live video streaming.

We map the walking speed of the user to the power of the robot engines. Thus, the faster the user walks, the faster the robot will move. In our application, we know the maximal speed of the robot and the mean value of human walking speed. We fit with a scale factor the range of the user's walking speed to the range of the robot's.

By image processing, we analyze both the user's movements and the rotation speed of the treadmill's endless band. One webcam is affected to analyse the hand gestures to indicate heading direction to the robot and a second one to analyse the walking speed to be mapped to the robot's engines. Figure 4 shows the installation.

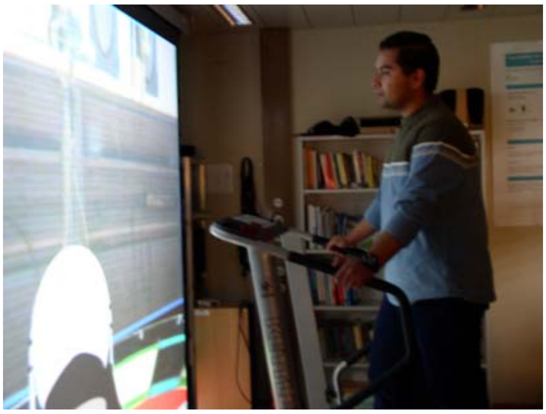

Figure 4: "Caddie paradigm" interface: treadmill and large projection screen.

The analysis algorithm compares the pictures shot with the webcam. It looks for changes in the pre-defined regions (left, right, above). Walking speed is calculated by considering the frequency of appearance of a marker attached to the endless band.

Robot Control System:

The mobile robot is a four-wheel vehicle built using the Lego Mindstorms Robotics Invention System 2.0® kit. It is controlled by the RCX (yellow brick) which contains a built-in microprocessor (see figure 5). It can execute autonomous behaviours coded on a PC and loaded through the brick's IR interface. We chose to bypass this functionality and use the RCX as a gateway for direct controlling the motors/sensors through a laptop or a PDA. The motors can turn in both directions with 8 different speeds. By setting two different speeds on the engines, the robot can turn. On the front, there is a bumper with two Boolean contact sensors which allow for collision detection on the left or right sides of the robot. The laptop or PDA runs a program, which can both evaluate the Boolean position of the collision sensors and turn on the motors to move the robot.

Figure 5: Mobile robot remotely controlled through a PDA.

The robot is equipped with a wireless "spycam". The video stream is acquired and displayed on the large screen.

There are two possibilities to communicate with the Lego Robot:

- Laptop - RCX. Communication is established between the infrared port of the RCX and the Lego USB Tower® connected to a laptop.[1]
- PDA - RCX. A PDA sends commands to the RCX via an Infrared Serial Interface developed in-house. This permits to have a fully wireless system.

Mediator Control System:

The master PC or mediator PC manages all the system and maintains the coherence of the of the data streams.

Three main kinds of data streams are exchanged between mediator world and input output system.

- Video stream coming from the robot to the mediator PC.
- Messages coding the position and orientation to send to the robot control system.
- Messages coding the information from input devices: Treadmill system or joystick.

A semi-immersive system displays video from the robot-mounted webcam and provides a virtual representation of the controlled robot from a third-person perspective. The virtual robot allows for visualizing the movement of the real one. When the user indicates the robot to move or turn, the virtual robot plays a short animation to indicate that the order is been executed. We do the same as in video games; the virtual robot slightly turns left/right or advances in a restricted space to indicate the order was received.

Once the order has been executed the virtual robot comes back to its initial position. Therefore, it is an indicator of intention. The virtual robot can inform the user about events and messages coming from the real robot. This helps to create a better mental representation of the different actions.

5. Discussion and further work

We have shown the feasibility of implementing a mediator interface following the "caddie paradigm". Several lessons were learnt from preliminary tests with the implemented prototype.

The free locomotion system allows for using hands in other tasks different from driving, e.g. manipulating other interfaces such as a handheld device. Simple gestures are required only to change the sense or direction of the robot.

Mapping the speed of the robot to the walking speed of the user is an innovative technique that can be used at different levels of precision. In fact the user can send very precise orders to the robot by walking slowly and performing accurate gestures.

After trying the system for a while, it becomes natural and intuitive. The "caddie paradigm" truly exploits the intuitiveness of a well-known human task.

The use of a virtual representation (third-person view) together with the real-time video acquired by the robot eases the task of creating a spatial representation in the user's mind. In fact, recent studies show that one of the best locations for an on-board camera in the context of teleoperation of a mobile robot is from a third-person perspective. This configuration allows for having an overall view of the scene and eases the driving of the tele-operated vehicle. Our interface simulates this third-person perspective by mixing the video and the virtual robot. This visualization could be improved by using a 3D model of the environment under exploration. We intend to incorporate more information in the virtual environment such as a map of the ground under exploration. Using a GPS or a similar localisation mechanism, we could show the position of the robot in the remote environment. We believe this would improve the control and ease the exploration of inaccessible locations.

Other information that can be displayed through the virtual representation of the robot includes collisions or close obstacles. Such information can be represented as a colour change in the affected part of the robot.

Additional more elaborated gesture recognition could be incorporated allowing the user to issue more complex commands to the remote entity.

We can conclude that the "caddie paradigm" is a promising alternative for controlling mobile robots and/or exploring virtual environments. Walking behind a virtual robot and gesturing revealed to be a very intuitive interaction technique.

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